PASSIVEHOUSE SYMPOSIUM 2012

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Implementation of ventilation in existing schools

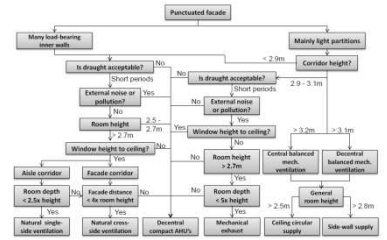
– a criteria list towards passive schools

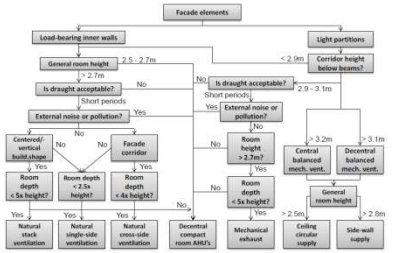
Background

- Part of trans-European SchoolVentCool project for retrofitting of high-performance schools

Method

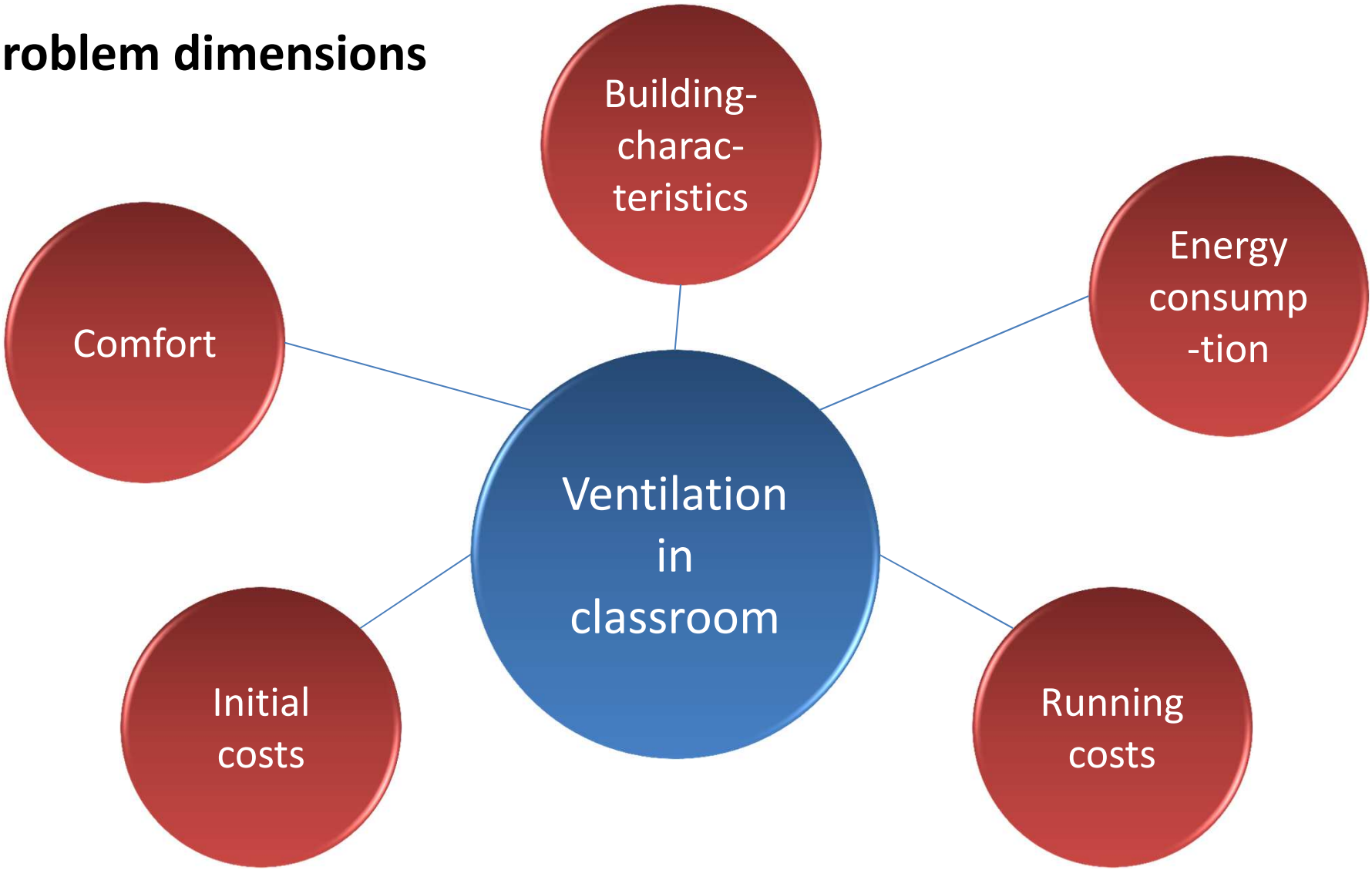
- Problem complex ‘Ventilation in classrooms’
- Decomposition of problem complex into dimensions
- School building categories
- Presentation of *design criteria/considerations* within each dimension
- Design considerations assembled and prioritized in design guide flow chart





- Criteria/design considerations based on standards, calculations, handbooks, guidelines, industry experience and research

Problem dimensions



Building characteristics

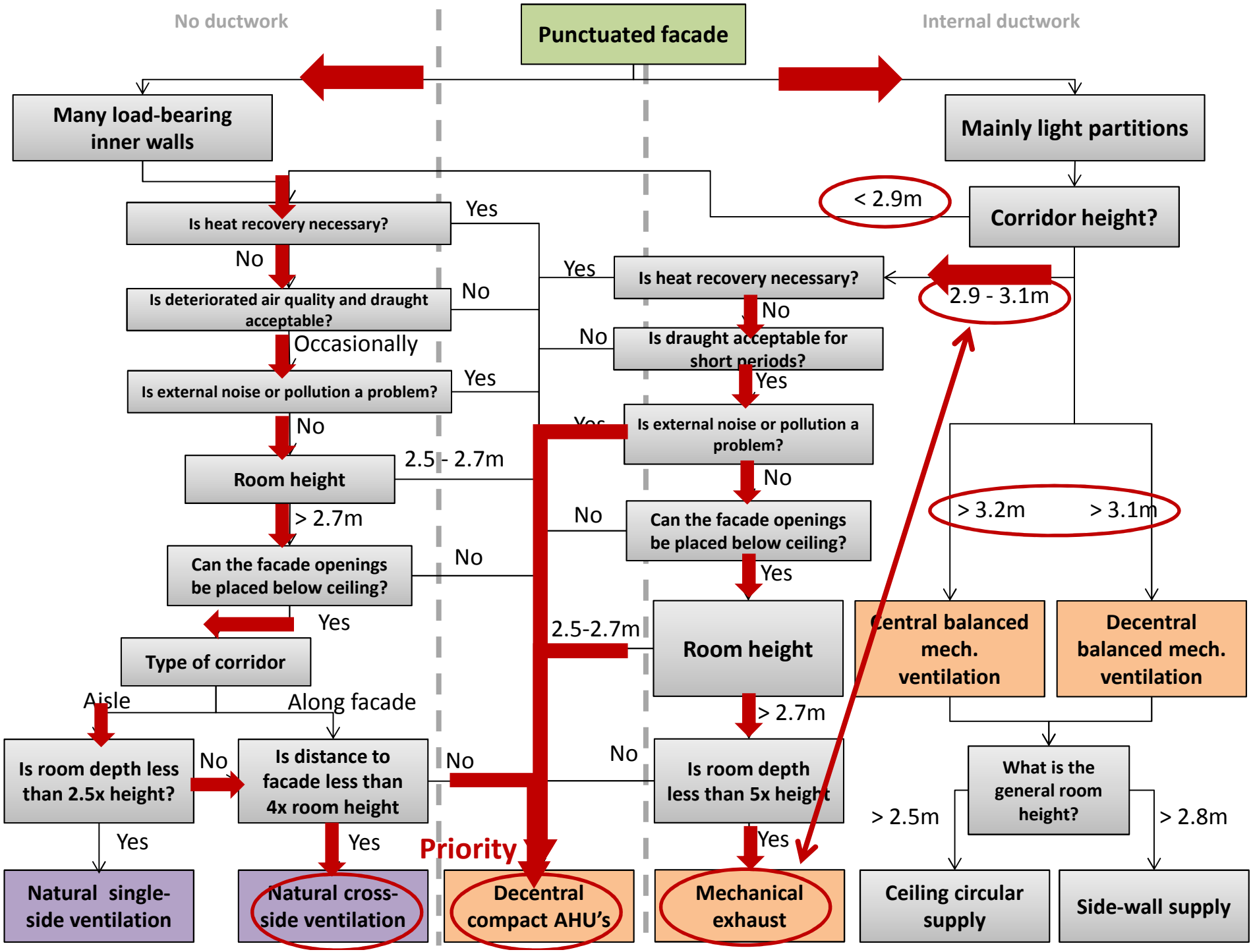
Façade structures	Punctuated façade	Façade elements
Façade type		
Characteristics	Massive structures perforated with windows	Skeleton structures with light facade elements
Structural elements	Monolithic load-bearing external walls	Load-bearing columns in façade or behind façade. Sometimes horizontal beam in façade restricts window size
Glazed façade	Low area	High area

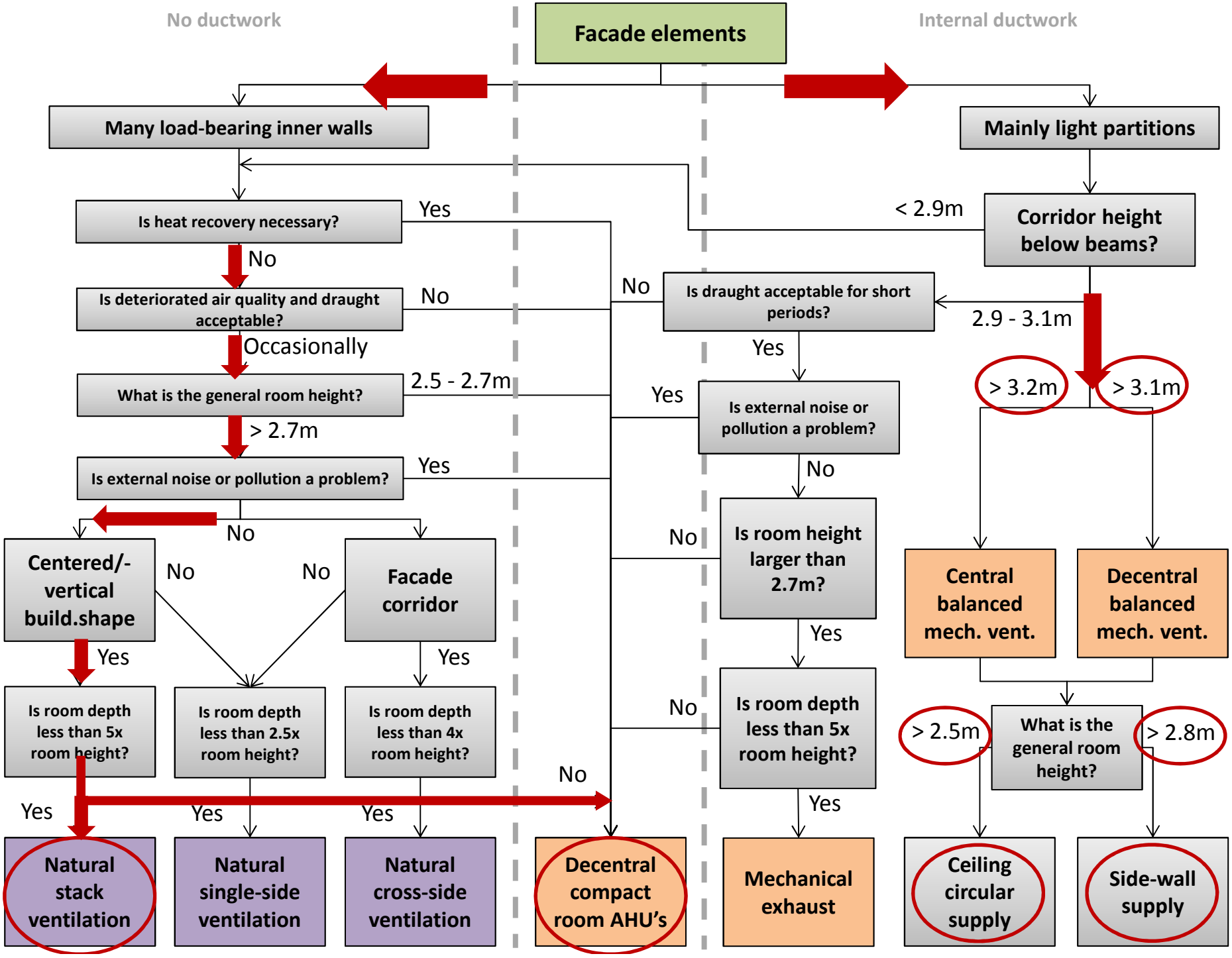
Drawings courtesy of Sonja Geier, AEE INTEC

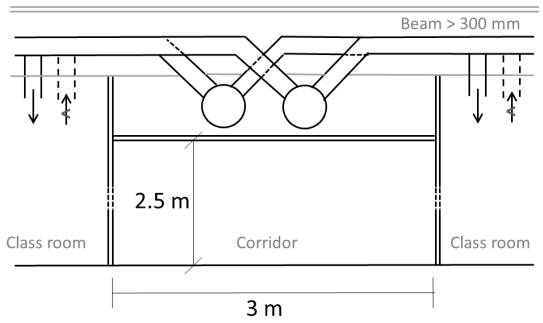
Ventilation systems are prioritized with regard to their ability:

- to maintain air quality
- to recover heat (passive standard)

1. Central or decentral balanced mechanical
2. Decentral compact units
3. Mechanical exhaust
4. Stack ventilation (natural)
5. Cross ventilation (natural)
6. Single-side ventilation (natural)


No ductwork
Punctuated facade
Internal ductwork
Many load-bearing inner walls
Mainly light partitions
Is heat recovery necessary?
Yes
No
Is deteriorated air quality and draught acceptable?
No
Occasionally
Is external noise or pollution a problem?
Yes
No
Room height
2.5 - 2.7m
> 2.7m
Can the facade openings be placed below ceiling?
No
Yes
Type of corridor
Aisle
Along facade
Is room depth less than 2.5x height?
No
Is distance to facade less than 4x room height
Yes
Yes
Natural single-side ventilation
Natural cross-side ventilation
Priority
Decentral compact AHU's
Yes
Is heat recovery necessary?
No
Is draught acceptable for short periods?
No
Yes
Is external noise or pollution a problem?
No
Can the facade openings be placed below ceiling?
No
Yes
2.5-2.7m
Room height
> 2.7m
Is room depth less than 5x height
No
Yes
Mechanical exhaust
< 2.9m
Corridor height?
2.9 - 3.1m
> 3.2m
> 3.1m
Central balanced mech. ventilation
Decentral balanced mech. ventilation
What is the general room height?
> 2.5m
> 2.8m
Ceiling circular supply
Side-wall supply


No ductwork
Facade elements
Internal ductwork
Many load-bearing inner walls
Mainly light partitions
Is heat recovery necessary?
Yes
No
Is deteriorated air quality and draught acceptable?
No
Occasionally
What is the general room height?
2.5 - 2.7m
> 2.7m
Is external noise or pollution a problem?
Yes
No
Centered/-vertical build.shape
No
No
Facade corridor
Yes
Yes
Is room depth less than 5x room height?
Is room depth less than 2.5x room height?
Is room depth less than 4x room height?
Yes
Yes
Yes
No
Natural stack ventilation
Natural single-side ventilation
Natural cross-side ventilation
Decentral compact room AHU's
No
Is draught acceptable for short periods?
Yes
Yes
Is external noise or pollution a problem?
No
No
Is room height larger than 2.7m?
Yes
No
Is room depth less than 5x room height?
Yes
Mechanical exhaust
< 2.9m
Corridor height below beams?
2.9 - 3.1m
> 3.2m
> 3.1m
Central balanced mech. vent.
Decentral balanced mech. vent.
> 2.5m
What is the general room height?
> 2.8m
Ceiling circular supply
Side-wall supply

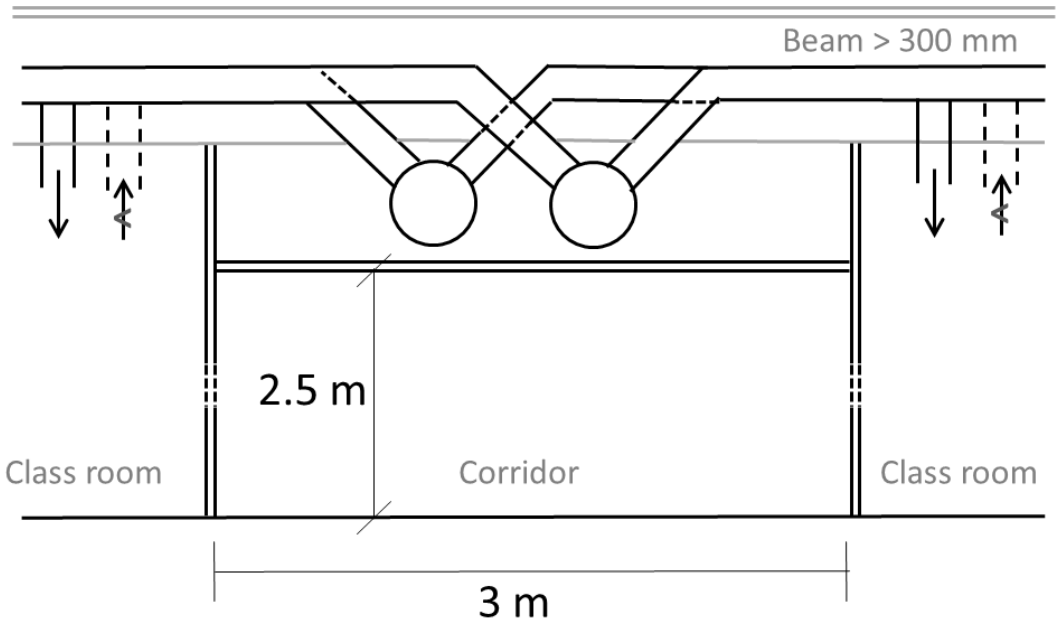


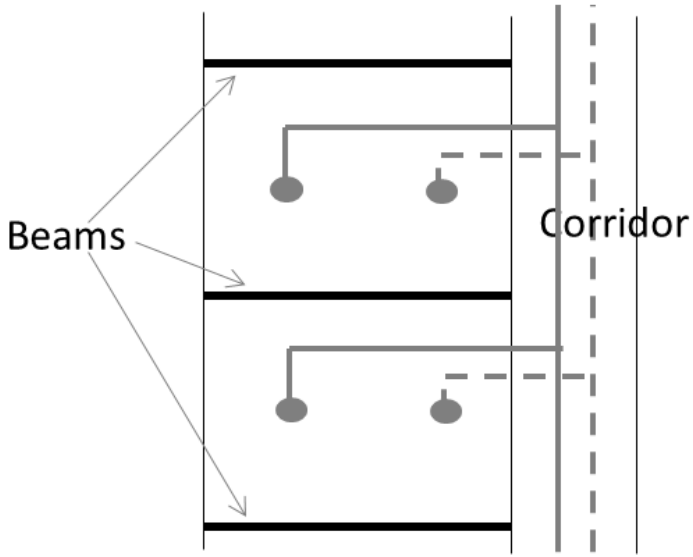
Duct sizing

- Average frictional pressure drop of 1.5 Pa/m2

Vertical space estimates of horizontal ducts	Central balanced	Central balanced	Decentral Balanced	Exhaust
Serviced classrooms	8	8	4	4
Supply ducts per room	1	2	2	1
Main duct Ø	400 mm	400 mm	315 mm	315 mm
Cross. distrib. Ø	200 mm	160 mm	160 mm	-
Suspended ceiling	50 mm	50 mm	50 mm	50 mm
Installation space	70 mm	70 mm	70 mm	50 mm
Sum	720 mm	680 mm	600 mm	420 mm
Rectangular duct space savings	-200 mm	-150 mm	-150 mm	-150 mm

Building typologies and space for ductwork





Investigated ventilation types

- Natural ventilation
  - Fresh air supply directly from outside
  - No pre-conditioning, heat recovery
  - Limited airflow control
- Mechanical ventilation
  - Fan air transport
  - Possibility of pre-conditioning, heat recovery and airflow control
- Hybrid systems
  - Combinations of the above

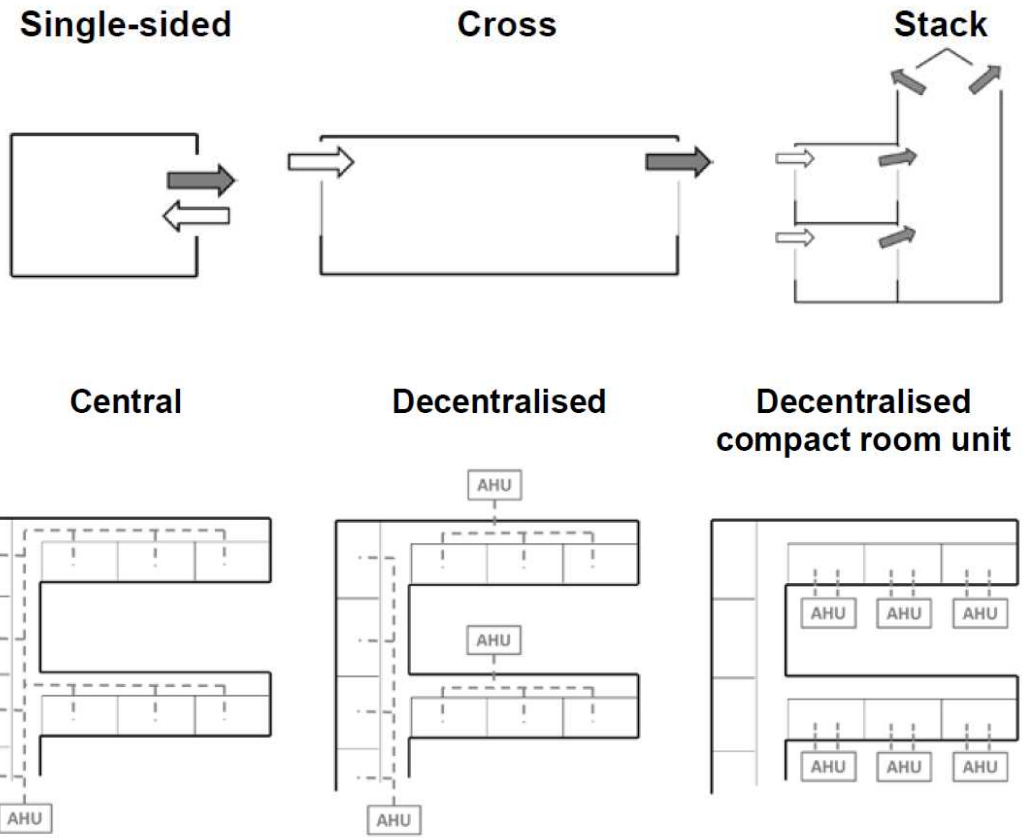


FIGURE 3a: ONE AIR HANDLING UNIT AND LARGE DUCTS VENTILATE LARGE AREAS

FIGURE 3b: MULTIPLE AIR HANDLING UNITS AND SMALLER DUCTS FOR SMALLER AREAS

FIGURE 3c: COMPACT AIR HANDLING UNIT IN EACH ROOM ELIMINATES DUCTS

Comfort criteria

- Thermal comfort
  - Optimum range for learning: 20-21C
- Ventilation (air quality)
  - Optimum air quality: <1000 ppm
  - country specific requirements: 5-7 l/s per person

	Denmark Building Code [1]	Austria EN13779 IDA3	Belgium EN13779 IDA3	England Bld. Bulletin 101 [4]	USA ASHRAE Standard 62.1-2001
Min vent. flow rate in classrooms	5,7 l/s per person	5,5 l/s per person	6,1 l/s per person	3/5 l/s per person (nat./mech)	7 l/s per person
Noise, L_{Aeg}	35 dB(A)	-	-	35 dB(A)	-
Additional demands	Ctrls for 1000 ppm	Ctrls for 1000 ppm	-	Ctrls for 8 l/s per pers.	-

TABLE I: REQUIRED VENTILATION FLOW RATES IN CLASSROOMS IN DIFFERENT COUNTRIES

Comfort criteria - Room supply

- Close to occupied zone at low momentum (displacement ventilation)
- Outside (above) occupied zone at high momentum (mixing ventilation)
- Prioritize supply outside the comfort zone to minimize draught
- *Demands for design of displacement ventilation are too high for schools*

Energy criteria

- Pressure drop
  - Recommended: 1-2 Pa/m frictional drop
  - Low energy consumption, low noise, lower leakage
- Heat recovery
  - At approx. 85%, heating coil can be discarded because minimum supply T>16°C
- Cooling
  - Not achieved by increasing ventilation airflow, but….
  - …by using free cooling by night ventilation
  - This correspond to approx. 20 W/m2 cooling, provided:
    - 4°C temperature rise allowed, e.g. 20->24°C
    - 6 hours school day
    - some heavy constructions, e.g. concrete slabs

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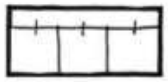
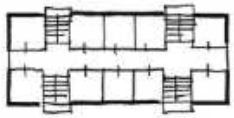
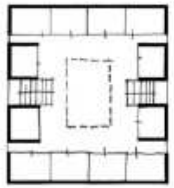
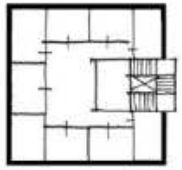
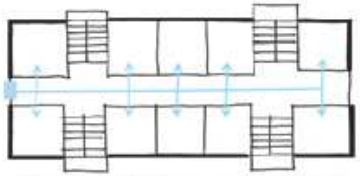
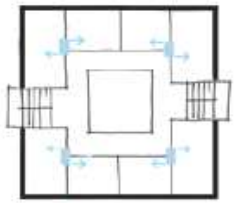
Building characteristics

Internal structures	Horizontal low	Horizontal high	Centered	Vertical
Building shape				
Floor plans				
Structural elements	Internal load-bearing walls	Internal load-bearing walls	Columns and beams with light partitions, some stabilizing walls	Internal load-bearing walls
Main duct routing	 Horizontal supply duct		 Vertical supply ducts	
Room height	Determ. by slabs,low	Determined by slabs, high	Determined by slabs	Determ. by slabs, low
Corridor height	Same as room height	Same as room height	Determined by beams	Determined by beams

Drawings courtesy of Sonja Geier, AEE INTEC

Relative construction costs

- changes compromising structural stability are relatively more expensive
- I.e. ductwork (hence mechanical vent.) is more expensive with many load-bearing partitions

Relative running costs

- Serviceability, access and service time
- Approx. service costs of new parts
- Lifespan of vital parts
- I.e. central systems are cheaper to service than decentral systems

Design chart assumptions

Assumptions	Values
Facade length x room width	8 x 6 m
Minimum room height	2.5 m
Occupancy	24 persons
Occupant heat load	80 W/person
Occupant density	2 m^2/person
Solar load, approx.	10 W/m^2 30% glazed facade, ext. shd.
Lighting load	0 W/m^2 (off when sun is shining)
Night cooling, approx.	-20 W/m^2 (see Table II)
Transmission loss, approx.	0 W/m^2 (very low in passive schools)
Total heat load	40+10-20 = 30 W/m2
Design rate for duct sizing	Table I: 5.7 l/s per pers. (20.5 m^3/h)
Design rate for room supply	CO_2: 7.5 l/s per pers. (27 m^3/h)
Variable-air-vol. controls	Redirects flow and shuts down unused rooms
Natural ventilation	Bottom-hung windows located below ceiling
Mech. ceiling supply	4 Lindab LCA circular diffusers Ø160, noise <20 dB(A)
Mech. side-wall supply	2 Lindab PR1 grilles 500x300 mm placed symmetrically, noise ~27 dB(A)

Conclusion

- Design considerations listed for implementing ventilation in existing (passive) schools
- Illustration of criteria list in the condensed form of design charts
- The paper focuses on the relations between internal building structure, façade, and ventilation characteristics

Remarks

- Choose decentral compact units, unless you have space for central ductwork below beams and in rooms (beware of noisy ones)
- Only consider natural ventilation if heat recovery is not necessary (e.g. for summer ventilation), and if you do select it, carefully design to fulfill the criteria (height/depth ratios etc.)